Appendix D
Generic Detailed Hydrologic Engineering Management Plan (HEMP) for a Flood Damage Reduction Study

D-1. General

This sample detailed HEMP would be appropriate for the hydrologic and hydraulic analysis associated with a typical Corps feasibility report for an urban watershed. It would be prepared at the end of reconnaissance-phase study or start of the feasibility phase. The intent of the hydrologic engineering analysis would be to determine existing and future discharge-frequency and stage-discharge relationships at key points in the study area, along with flooded area maps by frequency. This analysis would be performed without project and for various flood reduction components that are considered feasible for relief of the flood problem.

D-2. Preliminary Investigations

This initial phase includes a literature review of previous reports, obtaining the available data, and requesting additional information needed to perform the investigation.

a. Initial preparation.

(1) Confer with the other disciplines involved in the study to determine the objectives, the hydrologic engineering information requirements of the study for other disciplines, study constraints, etc.

(2) Scope study objectives and purpose.

(3) Review available documents.

(a) U.S. Geological Survey reports.

(b) Previous Corps work.

(c) Local studies.

(d) Hydrologic engineering analysis for reconnaissance report.

(e) Initial Project Management Plan.

(f) Other.

(4) Obtain hydrologic (historic and design discharges, discharge-frequency relationships, etc.) and hydraulic (high-water marks, bridge designs, cross sections, etc.) data.

(a) Local agencies (city/county highway departments, land use planning, etc.).

(b) State (state highway departments, planning agencies, water resource agencies, etc.).

(c) Federal U.S. Geological Survey (USGS), U.S. Soil Conservation Service (SCS), U.S. Bureau of Reclamation (USBR), etc.

(d) Railroads.

(e) Industries.

(f) Other.

(5) Scope major hydrologic and hydraulic activities.

(6) Prepare detailed HEMP.

(7) Obtain study area maps.

(a) County highway maps.

(b) USGS topographic quadrangle maps.

(c) Aerial photographs.

(d) Others.

(8) Estimate location of cross sections on maps (floodplain contractions, expansions, bridges, etc). Determine mapping requirements (orthophoto) in conjunction with other disciplines.

b. Field reconnaissance.

(1) Interview local agencies, and residents along the stream, review newspaper files, etc., for historic flood data (high-water marks, frequency of road overtopping, direction of flow, land use changes, stream changes, etc.). Document names, locations, and other data for future reference.

(2) Finalize cross-section locations/mapping requirements.

(3) Determine initial estimate of "n" values for later use in water surface profile computations.

(4) Take photographs or slides of bridges, construction, hydraulic structures, and floodplain channels and overbank areas at cross-section locations. Consider dictating notes to a hand-held tape recorder to get a complete and detailed record.

c. Survey request. Write survey request for mapping requirements and/or cross sections and high-water marks.

D-3. Development of Basin Model (HEC-1)

This phase of the analysis involves the selection of historic events to be evaluated, the development of runoff parameters from gaged data (and/or regional data from previous studies) and correlating these data to ungaged basins and the calibration of the basin model to historic flood events. This step assumes that at least some recording stream gage data are in or near the study watershed.

a. Calibration of runoff parameters.

(1) Select historic events to be evaluated based on available streamflow records, rainfall records, high-water marks, etc.).

(2) From USGS rating curves and time-versus-stage relationships for each event, develop discharge hydrographs at each continuously recording stream gage. Estimate peak discharge from flood crest gages.

(3) Develop physical basin characteristics (drainage areas, slope, length, etc.) for basin above each stream gage.

(4) Select computation time interval (Δt) for this and subsequent analyses. The computation interval must:

(a) Adequately define the peak discharge of hydrographs at gages.

(b) Consider type of routing and reach travel times.

(c) Have three to four points on the rising limb of the unit hydrograph for the smallest subarea of interest.

(d) Consider types of alternatives and future assessments.

(5) Using all appropriate rain gages (continuous and daily), develop historic storm patterns that correspond to the selected recorded runoff events for the basins above the stream gages.

(a) Average subarea totals from isoheytal maps or total gage precipitation weightings.

(b) Temporal distribution from weightings of nearby recording rain gages.

(6) Determine best estimate unit hydrograph and loss rate parameters for each event at each stream gage by calibrating to recorded flood hydrographs.

(7) Make adjustments for better and more consistent results between events at each stream gage. Adjustments are made to:

(a) Starting values of parameters and/or

(b) Rainfall totals or patterns (different weightings of rain gages).

(8) Hold constant the most stable parameters, or relationships between parameters, and resimulate rainfall/runoff process to estimate other parameters.

(9) Adopt final unit hydrograph and base flow parameters for each gaged basin.

(10) Re-simulate with adopted parameters held constant to estimate loss rates.

(11) Use adopted parameters of unit hydrographs, loss rates, and base flow to reconstitute other recorded events not used in the above calibration to test the correctness of the adopted parameters and to "verify" the calibration results.

b. Delineation of subareas. Subareas are delineated at locations where hydrologic data are required and where physical characteristics change significantly.

(1) Index locations where economic damage computations are to be performed.

(2) Stream gage locations.

(3) General topology of stream system.

(a) Major tributaries.

(b) Significant changes in land use.

(c)   Significant changes in soil type.

(d)   Other.

(4)   Routing reaches.

(5)   Location of existing physical works (reservoirs, diversions, etc.) and potential location of alternate flood reduction measures to be studied.

c.   Subarea rainfall-runoff analysis of historic events.

(1)   Subarea rainfall.

(a)   Average subarea rainfall from isohyetal maps or weighting of total gage precipitation.

(b)   Temporal distribution from weighing in accordance with information from nearby recording rain gages.

(2)   Average subarea loss rates.

(a)   From adopted values of parameter calibration.

(b)   From previous studies of similar basins in the region.

(c)   Others.

(3)   Unit Hydrograph Parameters.

(a)   From relationships based on calibration results at stream gages (Section II) and physical basin characteristics.

(b)   From previous regional study relationships of unit hydrograph parameters and physical basin characteristics.

(c)   From similar gaged or known basins.

(d)   From judgment, if no data are available.

d.   Channel routing characteristics.

(1)   Modified Puls from water surface profile computations (Hydrologic Engineering Center (HEC-2)).

(2)   Optimized from stream gage data (HEC-1).

(3)   Adopted parameters from previous studies, experience, etc.

(4)   Derived from reach hydraulics (Muskingum - Cunge).

e.   Reservoir routing (if reservoirs are present). This type of routing must be performed where storage has a significant effect on reach outflow values, with reservoirs being the most notable example. However, one must also apply these techniques where physical features warrant, such as roads crossing a floodplain on a high fill, especially where culverts are used to pass the flow downstream.

(1)   Develop surface area-capacity data (elevation-surface area-storage relationships).

(2)   Develop storage-outflow functions based on outlet works characteristics.

f.   Runoff hydrographs. Using the subdivided rainfall-runoff model, including existing projects and the routing information of Section D-3 above, generate runoff hydrographs for previously selected runoff events at desired locations. Final calibration of the hydrologic model is described in Section D-5.

D-4. Hydraulic Studies

These studies are used to determine water surface profiles, economic damage reaches, and modified Puls channel routing criteria (if used). This example assumes that an evaluation was previously made that a steady flow-rigid boundary water surface profile analysis is appropriate.

a.   Prepare water surface profile data.

(1)   Cross sections (tabulate data for each section).

(a)   Make cross sections perpendicular to flow.

(b)   Each cross section should be typical of the reach from half the distance to the next section both upstream and downstream of the current locations.

(c)   Develop effective flow areas. If modified Puls routing criteria are to be determined from water surface profile analyses, the entire section must be used (for storage) with high "n" values in the non-effective flow areas.

(2)   Refine "n" values from field reconnaissance and from analytical calculation and/or comparison with "n" values determined analytically from similar streams.

(3) Bridge computations--estimate how high the selected floods will reach on each bridge and select either:

(a) Normal bridge routine.

(b) Special bridge routine.

(4) Develop cross sections above and below bridges to model effective bridge flow (use artificial levees or ineffective flow area options, as appropriate).

b. Proportion discharges. Proportion discharges based on hydrologic analyses of historic storms and plot peak discharge versus river mile. Compute a series of water surface profiles for a range of discharges. Analysis should start below study area so that profiles will converge to proper elevations at study limits. May want to try several starting elevations for the series of initial discharges.

c. Manual check. Manually check all large differences in water surface elevations across the bridge, say, greater than 3 ft.

d. Results. The results are a series of rating curves at desired locations (and profiles) that may be used in subsequent analyses. Additional results are a set of storage versus outflow data by reach which, along with an estimate of hydrograph travel time, allow the development of modified Puls data for the hydrologic model.

D-5. Calibration of Models to Historic Events

a. General. This study step concentrates on "de-bugging" the hydrologic and hydraulic models by recreating actual historic events, thereby gaining confidence that the models are reproducing the observed hydrologic responses. This effort would continue from the activities described in Paragraph D-3.

b. Calibration procedure.

(1) Check historic hydrographs against recorded data, make adjustments to model parameters, and rerun the model.

(2) If no stream gages exist, check discharges at rating curves developed from water surface profiles at high-water marks.

(3) Adjust models to correlate with high-water marks.

(4) Adopt hydrologic and hydraulic model parameters for hypothetical flood event analysis.

(5) Quantify uncertainty of the stage-discharge relationship at each site where damage analysis is to be performed. As appropriate, use recorded gage data, comparison of profile to high-water marks, minimum deviation, and engineering judgement.

D-6. Frequency Analysis for Existing Land-Use Conditions

The next phase of the analysis addresses how often specific flood levels will occur at all required points in the study watershed. The procedures include developing discharge-and stage-frequency relationships at stream gages (when available) through statistical analysis using recorded peak discharges and at other required locations using available hypothetical storm data.

a. Statistical analysis. Using the procedures described in Bulletin 17B (Water Resources Council 1982), determine and plot analytical and graphical frequency curves at each stream gage. Adopt stage/discharge frequency relations at each gage. Regional relationships, regression analyses, and the results of hypothetical storm studies will be used to extend the records for rarer floods.

b. Hypothetical storms (HEC-1).

(1) Obtain hypothetical frequency storm data from the National Oceanic and Atmospheric Administration (NOAA) HYDRO 35, National Weather Service (NWS) Technical Publications (TP) 40 and 49, or from appropriate other sources. Where appropriate, develop the Standard Project and/or the Probable Maximum Storm.

(2) Develop a rainfall pattern for each storm. Include precipitation depth-area adjustments, where necessary.

(3) Develop a corresponding hydrograph for each hypothetical event throughout the basin using the calibrated hydrologic model.

(4) If deemed necessary, calibrate model of each frequency event to known frequency curves. Adjust loss rates, base flow, etc. as required, while remaining within reasonable limits for each parameter. The peak flow frequency at each ungaged area is assumed to be consistent with calibrated peak flow frequencies at gaged locations.

(5) If streamflow data are insufficient to develop analytical frequency curves, use the following procedure:

(a) Obtain frequency curves from similar nearby gaged basins.

(b) Develop frequency curves at locations of interest from previous regional studies (USGS, Corps of Engineers, State, etc.).

(c) Determine frequency hydrographs for each event from hydrologic model and develop a corresponding frequency curve at the locations of interest throughout the basin.

(d) Plot all the frequency curves (including those using other methods if available) and, based on engineering judgement, adopt a frequency curve. The adopted curve may not be any of the developed curves, but simply the best estimate based on the available data.

(e) Calibrate the hydrologic model of each frequency event to the adopted frequency curve. The frequency curve at other locations may be determined from the calibrated model results, assuming consistent peak flow frequencies.

(6) Quantify the uncertainty in the discharge-frequency relationship at all locations where damage computations will be performed. As appropriate, use gage data, regression equations, calibrated models to determine equivalent length of record.

(7) Determine corresponding water surface elevations and profiles for selected frequencies from the rating curves developed by the water surface profile evaluations.

D-7. Future Without-Project Analysis

Where hydrologic and/or hydraulic conditions are expected to significantly change over the project life, these changes must be incorporated into the hydrologic engineering analysis. Urbanization effects on watershed runoff are the usual future conditions analyzed.

a. From future land use planning information obtained during the preliminary investigation phase, identify areas of future urbanization or intensification of existing urbanization.

(1) Types of land use (residential, commercial, industrial, etc.).

(2) Storm drainage requirements of the community (storm sewer design frequency, on-site detention, etc.).

(3) Other considerations and information.

b. Select future years in which to determine project hydrology.

(1) At start of project operation (existing conditions may be appropriate).

(2) At some year during the project life (often the same year as whatever land use planning information is available).

c. Adjust model hydrology parameters for all subareas affected by future land use changes.

(1) Unit hydrograph coefficients, usually reflecting decreased time-to-peak and decreased storage.

(2) Loss rate coefficients, usually reflecting increased imperviousness and decreasing infiltration characteristics.

(3) Routing coefficients, usually reflecting decreased travel times and storage capabilities.

d. Operate the hydrology model and determine additional discharge-frequency relationships throughout the watershed that represent future, without-project conditions.

e. Evaluate the need to adjust uncertainty parameters of stage-discharge and discharge-frequency relationships, compared to existing conditions.

D-8. Alternative Evaluations

For the alternatives jointly developed with the members of the interdisciplinary planning team, modify the hydrologic and/or hydraulic models to develop the effects of each alternative (individually and in combination) on flood levels. Alternatives can be either structural (reservoirs, levees, channelization, diversions, pumping, etc.) or non-structural (flood forecasting and warning, structure raising or relocation, floodproofing, etc.). Considerable less hydrologic engineering effort is necessary for modeling non-structural alternatives compared to structural.

a. Procedure.

(1) Consider duplicating existing and future without-hydrologic engineering models for individual analysis of

each alternative or component. The results provide exist-ing and future, with-project information for each alterna-tive to be evaluated.

(2) Most structural components are usually modeled by modifying storage-outflow relationships at the compo-nent location and/or modifying hydraulic geometry through the reach under consideration.

(a) Reservoirs--adjust storage-outflow relationships based on spillway geometry and height of dam.

(b) Levees--adjust cross-section geometry based on proposed levee height(s). Evaluate effect of storage loss behind levee on storage-outflow relationships and deter-mine revised discharge- and stage-frequency relationships downstream, if considered significant. Develop uncer-tainty relationship for the revised stage-discharge function.

(c) Channels--adjust cross-section geometry based on proposed channel dimensions. Evaluate effect of channel cross section and length of channelization on floodplain storage, modify storage-outflow in reach, and determine revised downstream discharge-frequency relationships, if considered significant.

(d) Diversions--adjust hydrology model for reduced flow downstream of the diversion and to identify where diverted flow rejoins the stream (if it does).

(e) Pumping--adjust hydrology model for various pumping capacities to be analyzed.

(3) Evaluate the effects of potential components on the sediment regime. Refer to guidance given in EM 1110-2-4000.

(a) Qualitatively--for initial screening.

(b) Quantitatively (where necessary)--for final selection.

b. Nonstructural components.

(1) Floodproofing/structure raises--elevations of design events primarily.

(2) Flood forecasting--development of real-time hydrology model, determination of warning times, etc.

c. Alternative evaluation and selection.

(1) Alternative evaluation and selection is an iterative process, requiring continuous exchange of information between a variety of disciplines. An exact work flow or schematic is not possible for most projects, thus Para-graph D-7 could be relatively straightforward for one or two components or quite complex, requiring numerous reiterations as more cost and design information is known and project refinements are made. Paragraph D-7 is usu-ally the area of the HEMP requiring the most time and cost contingencies.

(2) For the selected alternative, provide hydrologic information to environmental engineers for use in studies concerning the effects of the recommended project.

D-9. Hydraulic Design

This paragraph and Paragraph D-8 are partly intertwined, as hydraulic design must be included with the sizing of the various components, both to operate hydrologic engi-neering models and to provide sufficient information for design and costing purposes. Perform hydraulic design studies commensurate with the level of detail of the study process.

a. Reservoirs. Dam height, spillway geometry, spill-way cross section, outlet works (floor elevation, length, appurtenances, etc.), scour protection, pool guidetaking line, etc.

b. Levees. Levee design profile, interior flood control requirements, etc.

c. Channels. Channel geometry, bridge modifica-tions, scour protection, channel cleanout requirements, channel and bridge transition design, etc.

d. Diversions. May be similar to channel design activities, also would include diversion control (weir, gates, etc.). Where the diversions are tunnels, open chan-nel flow and pressure conduit hydraulic analyses may be necessary, depending on tunnel capacity and range of possible discharges.

e. Pumping. Capacities, start-stop pump elevations, sump design, outlet design, scour protection, etc.

f. Nonstructural. Floodproofing or structure raise elevations, flood forecasting models, evacuation plan, etc.

D-10. Hydrologic Engineering Reporting Requirements

The last step must thoroughly document the results of the technical analyses in report form. Hydrologic and hydraulic information presented will range from extensive for feasibility reports to minimal for a typical Feature Design Memorandum (FDM(s)).

a. Project Management Plan.

(1) Major hydrologic engineering activities in the preconstruction engineering and design (PED) phase.

(2) Time and cost for hydrologic engineering.

(3) Activity schedule.

b. Hydrologic Engineering Appendix.

(1) Text.

(2) Tables.

(3) Figures.

c. Environmental Impact Statement/Environmental Assessment Report.

(1) Hydrologic information/data as necessary.

(2) Portions of text, selected figures and tables.